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Human Performance Modelling in Manufacturing: Mental Workload and Task Complexity

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Extended Abstract

This work presents a project developed by an industry and academia consortium to improve the efficiency of production targets through the optimising Human Performance and reducing defect rates in manufacturing tasks where the human component is relevant. There are two test bed one in heavy vehicle production and one in a facility producing electronic components and equipment. This project is based on a systematic approach to Work field analysis and is structured on the following 6 main issues: (1) identification of the most critical areas that generate defects and safety problems with special emphasis on those characterised by a higher level of human activity, (2) definition of the Human Performance (HP) model, (3) definition of a set of observable variables to assess the HP model, (4) in situ data collection and measurements, (5) calibration of the HP model on the basis of data collection and finally (6) definition of production line improvement and model validation trough the observation of error rates for improved workstation [1]. The project requires rich integration of data from multiple sources: the data observed from field, Key Performance indicators (KPI) collected by the sensoring technology on the production line, the activity of operators (Human Factors theory), and their response. The resulting data will form the basis of an empirically based, cross-verified model of human performance that can be used to provide objective feedback to users increasing their awareness of risks related to their own human characteristics and impact the design of safety critical systems and current approaches for vocational training.

The model to assess the HP is based on an extension of the model introduced by Georg Rasch [2] to analyse categorical data, such as correct or incorrect execution of an assessment, as a function of the trade-off between (a) the respondent's abilities, attitudes or personality traits and (b) the item difficulty. In the Rasch model, the probability of a specified outcome (e.g. right/wrong results) is modelled as a logistic function of the difference between the person and item difficulty parameter. The mathematical form of the model is provided in formula 1. Let X_{ni} be a dichotomous random variable with binary values where, for example, $X_{ni}=1$ denotes a correct response and an $X_{ni}=0$ an incorrect response to a given assessment item. In the Rasch model for dichotomous data, the probability of the outcome is given by:

$$\Pr\ (X_{ni} = 1) = \frac{e^{\beta_n - \delta_i}}{1 + e^{\beta_n - \delta_i}} \qquad (1)$$

where β_n the ability of person n and δ_i the difficulty of item i .

In the applications under analysis the model has been chosen to represent the interaction between two macro factors:

- Task complexity (TC): that summarises all factors contributing to physical and mental workload requirements for execution of a given operative task, including environmental work factors such as noise and microclimatic aspects;
- Human capability (HC): that considered the skills, training and experience of the people facing the tasks. These factors represent both physical, mental and cognitive ability of workers.

TC is the result of the contribution of two main factor: “Mental Workload Demands” (MW) and “Physical Workload Demands” (PW), both associated to a single operative task.

PW factors are easily relatable to the physical, motion and postural efforts required to complete a given task, in fact bad ergonomics combined with time pressures have been estimated to cause about 50% of all quality deviations [3]. While assessing the MW demand factors on the field in relation to the actual industrial task requires a combination of subjective measurements and indirect task-related variable quantifications [4] such as the pace of the task and the amount of parts and variability involved in the assembly task. For the purpose of the current case study it was not possible to collect physiological measurements and cognitive normative tests.

Furthermore the MW demand assessment has to include all those factors that can reduce the amount of resources required to complete the task, these factors, that can be grouped into “Mental support Task” factor such as memory support visual tools, quality and effectiveness of training and logistic of the assembly parts/tools.

The interim results will be tested against industry needs/expectations and the dissemination of them will target International Safety and Health authorities, production line Designers and national standards authorities.

Empirical verification of some of the theoretical hypotheses previously formulated in the literature about human performance modelling would be extremely beneficial to the scientific community in the area of workplace, task and equipment design and relevant to the active work of the ISO Technical Committee 159/SC 4 on ergonomics of human-system interaction.

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